Graphite Reactor Decommissioning

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Introduction

- Summary of UKAEA
- GLEEP reactor experience
- BEPO reactor experience
- Responses to questions
- Questions for you
- Summary

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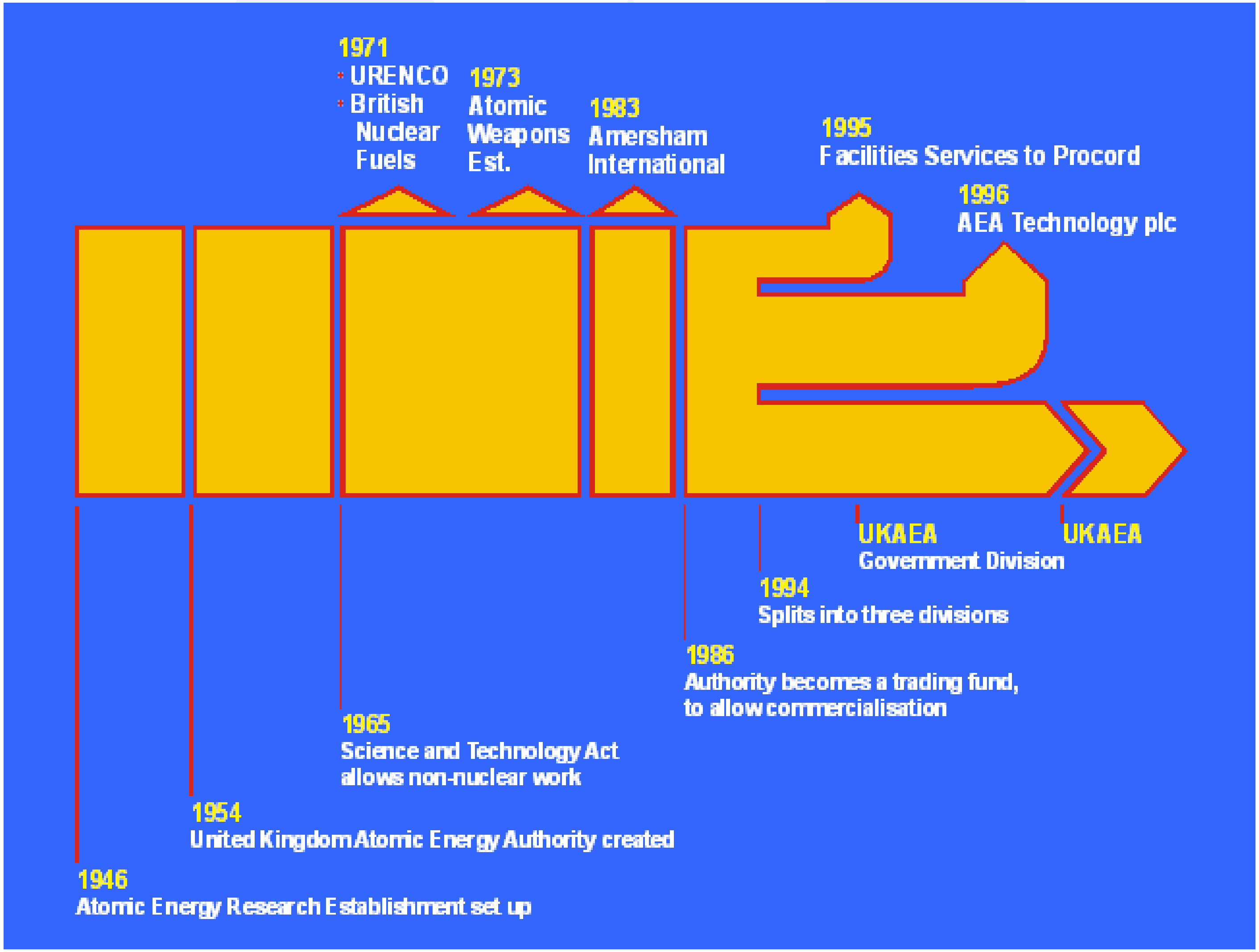
Evolution of UKAEA



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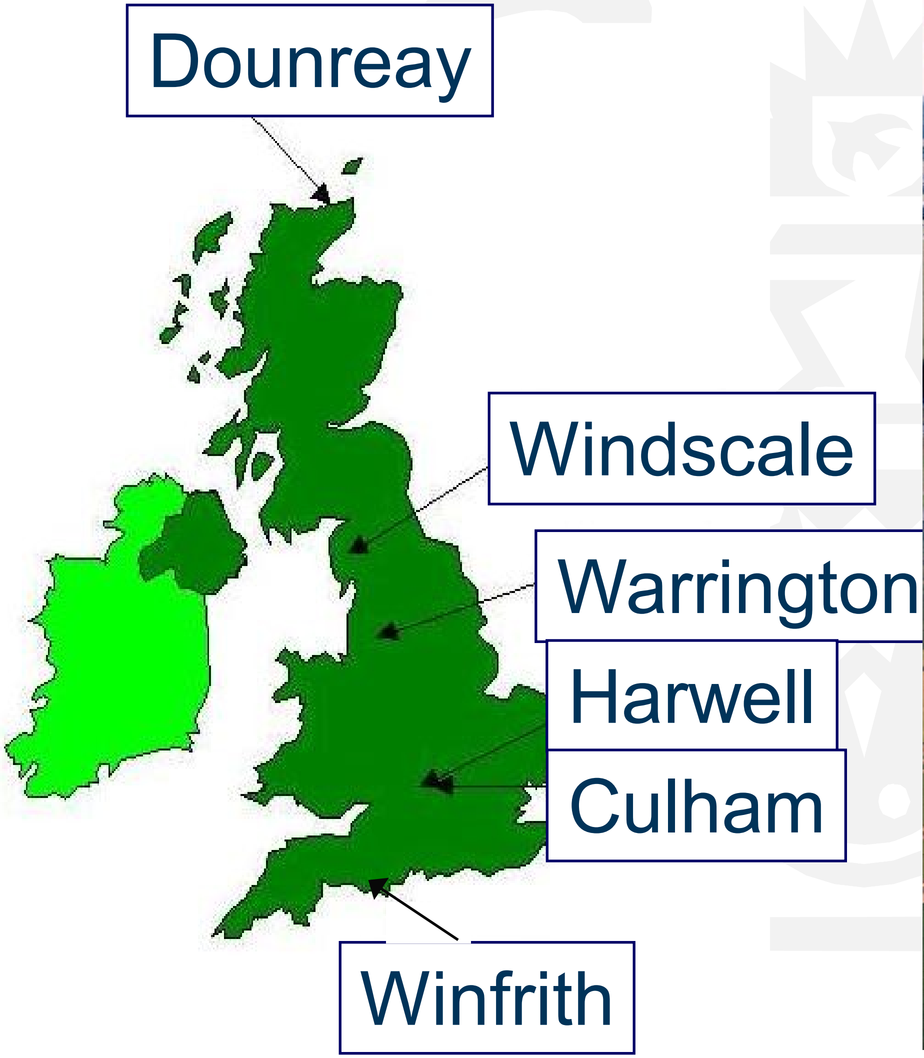
UKAEA sites



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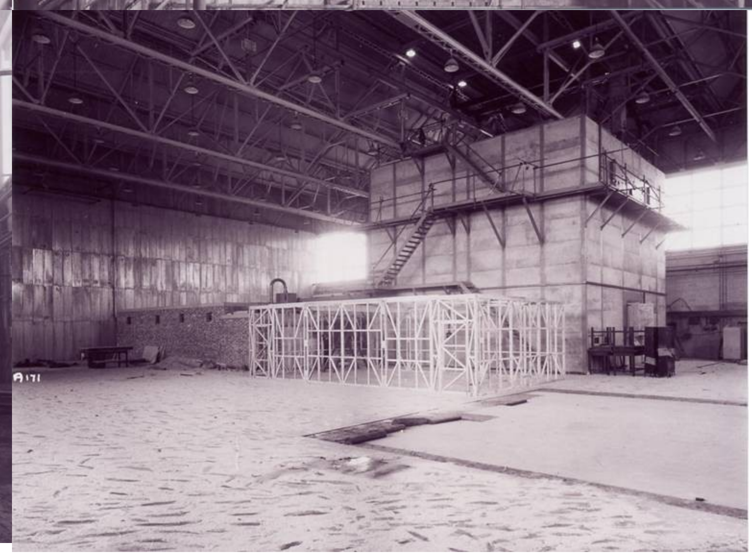
GLEEP – construction photographs



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GLEEP reactor

- First reactor in Western Europe – built in the mid-1940's and started operating in August 1947
- Used for experimental studies and calibrations
- Graphite cube of 6.4 m sides, 505 t of graphite
- 682 fuel channels – natural uranium/Al clad
- Core shielded by 1.5 m of barytes concrete
- Initially operated at 60 kW(th) for a year but then operated at 3kW(th) until closure
- Average operating temperature of 18 ^{o}C
- Shutdown in 1990 after 43 years of operations.

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Decommissioning

- Defuelling performed in 1994
- Control rod and external equipment removal in 1995
- Brick by brick removal of the graphite core in 2003-2004, using the ‘drill and tap’ method
- Demolition of the concrete bioshield
- Hangar demolition and land remediation
- Land currently undergoing de-licensing scrutiny by the NII

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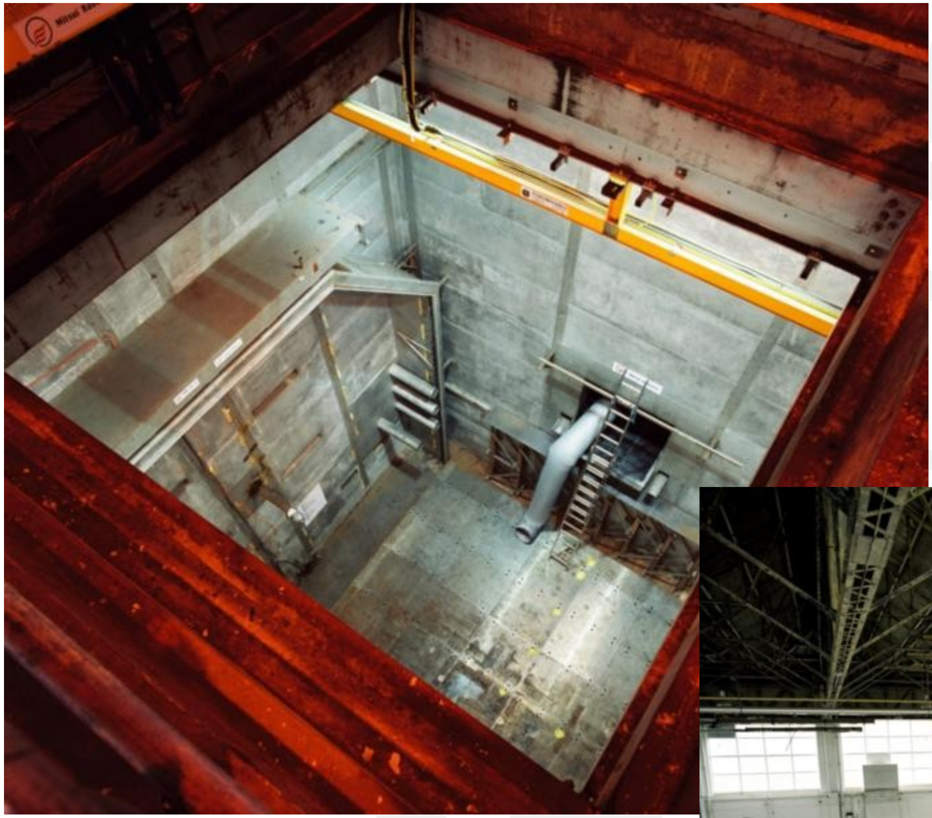
Decommissioning



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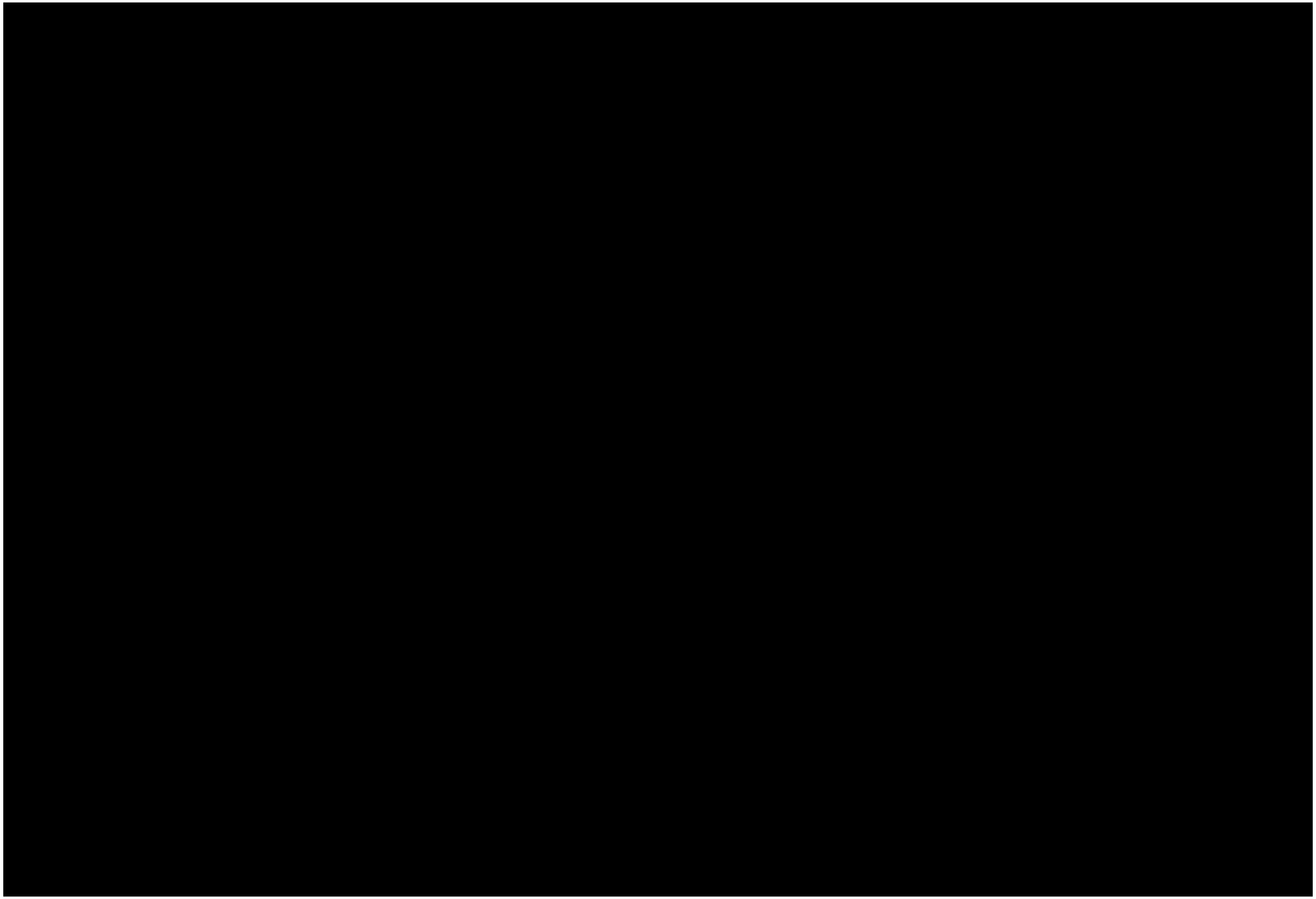
GLEEP decommissioning



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Waste handling

- Each graphite block was monitored and sampled on removal and tagged for inventory tracking purposes
- Blocks were then crushed and packaged into 200 litre drums
- Crushed graphite then incinerated to drive off H-3 and C-14
- Aerial discharge of tritiated water vapour and C-14 carbon dioxide several orders of magnitude under discharge authorisation
- Incineration was significantly cheaper than packaging the graphite for disposal at the LLWR near Drigg

Graphite incineration

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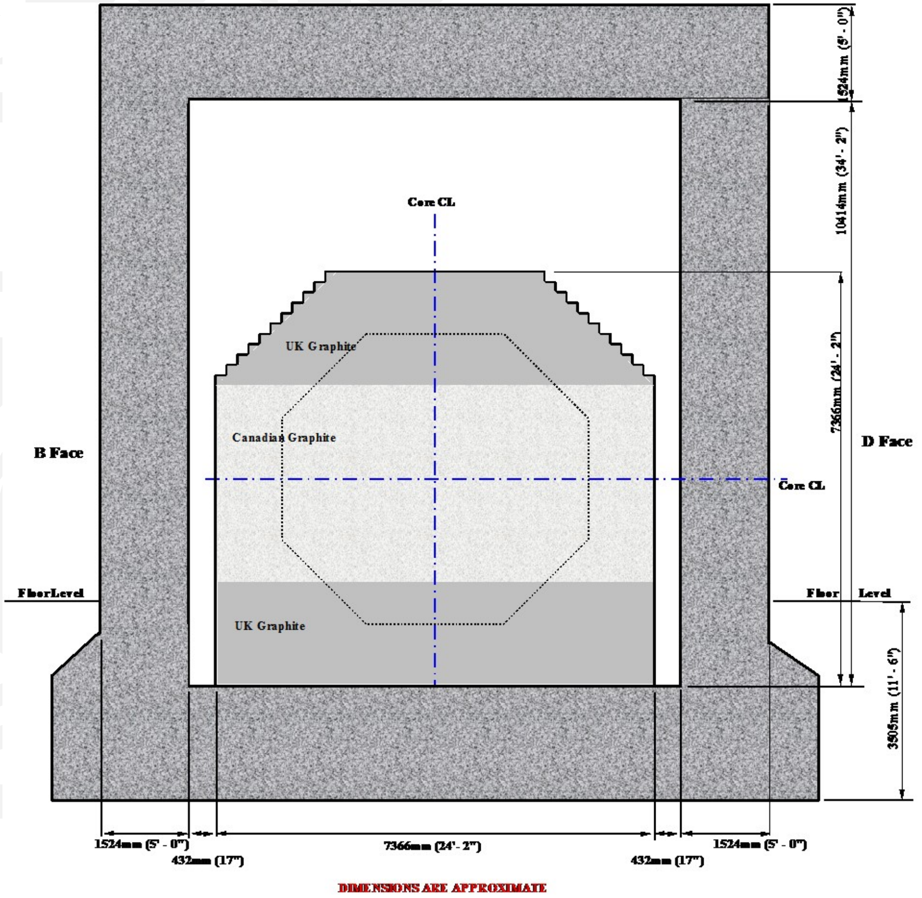
Waste characterisation

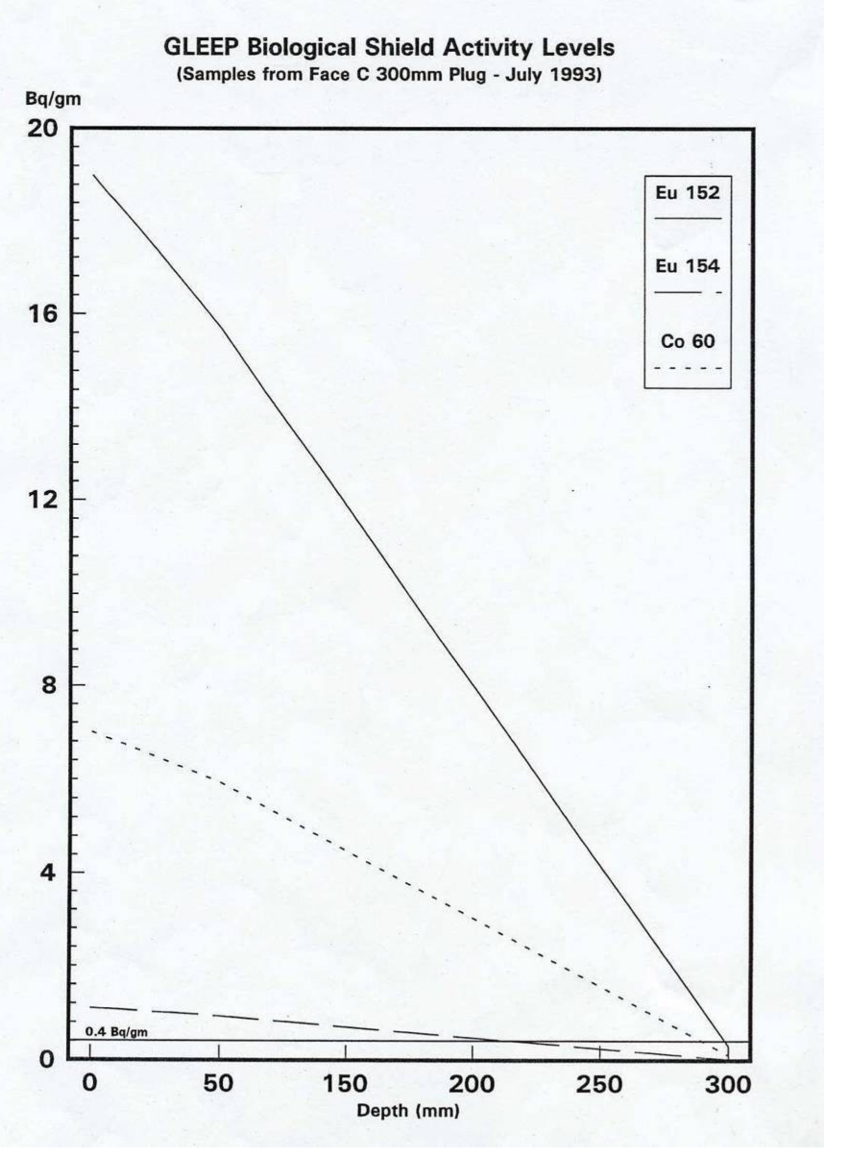
- Neutronic calculations undertaken to determine the inventory of the graphite
- Horizontal and vertical cores were drilled through the bioshield and graphite
- Significant levels of H-3 and C-14 (3.81 and 1.82 Bq/g) found in bioshield.
- Higher levels of C-14 found in fuel channels



Radionuclide inventory

Radionuclide	2001 Inventory from Core Samples (Bq)
Tritium	1.50E+11
Carbon - 14	9.01E+09
Calcium - 41	* bdl
Calcium - 45	2.87E+07
Iron - 55	1.48E+08
Cobalt - 60	5.88E+08
Nickel - 63	3.75E+08
Zinc - 65	5.42E+07
Barium - 133	1.27E+07
Caesium - 137	2.26E+07
Samarium - 151	1.34E+08
Europium - 152	6.16E+09
TOTAL	**1.67E+11**

* Decayed to below detectable limit



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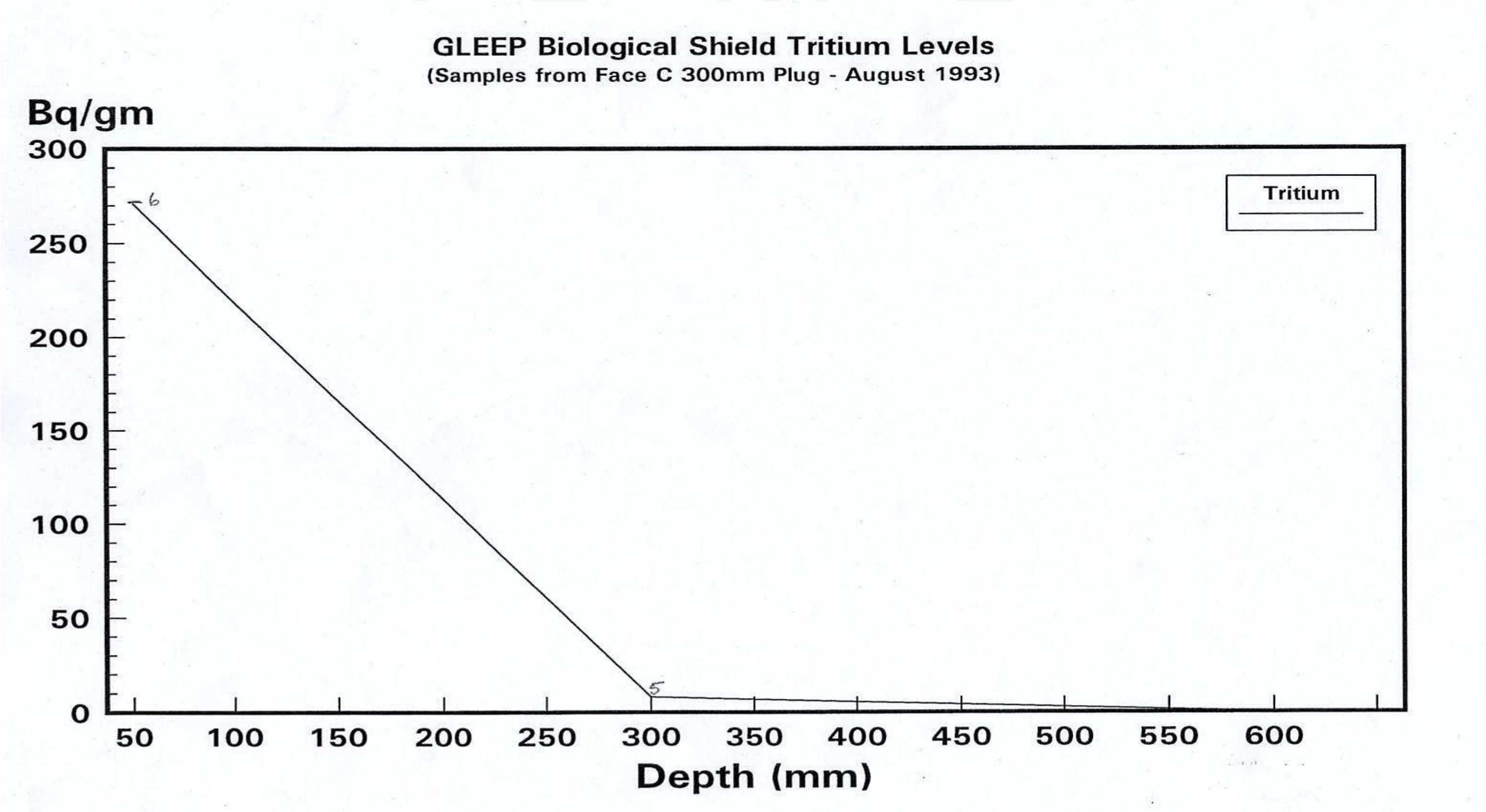
Radionuclide inventory



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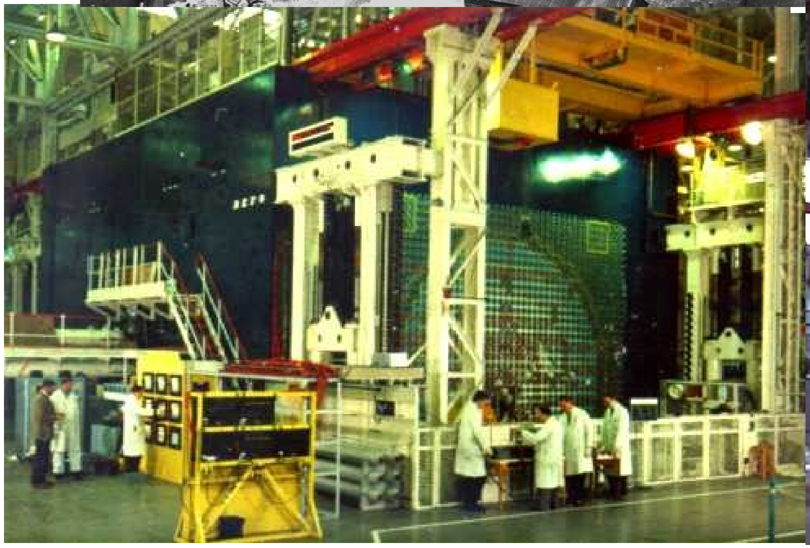
BEPO – construction and operation



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BEPO reactor

- Following the success of GLEEP BEPO was constructed at Harwell in the 1940’s
- BEPO started operation in July 1948
- Used to demonstrate that commercial power reactors would be viable, materials testing and production of radio-isotopes
- Graphite cube of 7.9 m sides, 766t of graphite
- 888 fuel channels – natural uranium/Al clad
- Operated at 6kW(Th)
- Shutdown in 1968.

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BEPO decommissioning strategy

- Immediately following closure, taken to Stage One decommissioning – removal of fuel and non-fixed items.
- 6 inch core taken through the side of BEPO to the centre showed residual Wigner energy
- Stage Two decommissioning 1993 – 2000.
  - Demolition of 56m chimney
  - Removal of cooling system
  - Demolition of associated buildings
  - Thermal shield constructed to protect against Wigner energy release.
- Currently under Care and Maintenance
- Plans to take further cores through the reactor to support characterisation

Brookhaven Questions

Doses on the GLEEP project

- Pile contained a total activity of 167 GBq of which over 95% came from H-3
- Possible for operators to enter the bioshield
- Typical dose rates were in the range of background to 80 μSv/hr
- Personnel issued with digital dose meters for the duration of the project and a daily personnel dose chart maintained
- Total accumulated dose for the project limited to 7mSv
- Contamination of 5 cps βγ and 1cps α

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Isotopic mix

- Inventory of the graphite dominated by C-14 and H-3 as expected (H-3 is 90% of total inventory), also Eu-152 and Eu-154
- Cl-36 of issue to UK ILW disposal requirements
- No contamination found in the fuel channels
- Small area of uranium contamination found fairly high up in the pile
- Concrete inventory dominated by tritium, C-14 and Ni-63

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Monitoring equipment

- Alpha and beta air sampling and analysis carried out within the reactor bioshield and points within the hangar
- Tritium in air analysis carried out in the bioshield and passive tritium monitoring carried out throughout the hangar
- No detectable activity from the removal processes was recorded
- Each drum of waste subjected to a 14 point gamma radiation survey

Experience with graphite

- Loose contamination during the project was minimal
- Graphite dust dealt with by tacky rags and hoovering as and when required
- All graphite blocks were hoovered on removal and covered in cling film
- Slippery surfaces were a particular hazard – no overshoes used, trainer type contact shoes, workers wore harnesses at all times
- Graphite removed using drill and tap, graphite cores were taken for analysis
- No fixatives for airborne control – only airborne control related to asbestos issue from a gasket at one end of the reactor. Used PVA tie down

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Fred's questions

- No issues with "hot particles"
- Scaling factors/fingerprints used all the time for UKAEA reactor decommissioning projects. Based on mass of graphite supported by gamma measurement of caesium contamination and pro-rate of other contaminants.
- For GLEEP this was backed up with analysis of core samples
- Health and safety issues discussed earlier
- No issues with ventilation during the reactor dismantling

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What went wrong?

- Tritium levels measured in the bio-shield higher than expected from previous calculations – due to “green” concrete
- Grade A graphite at the core of GLEEP came from Canada and was much harder than the lower grade British graphite surrounding it. New drill and tap device had to be developed for the softer graphite
- Wider weight range of graphite blocks than expected, specifications for lifting need to be aware of this
- Asbestos seal found in the core came as a surprise

My questions for you

- Cadmium coated born shot – more of an issue than the graphite?
- Is the U in the reactor from fuel failure, activation of rare earths or from the “tramp” U
- Has increased levels of C-14 been seen on the edge of the fuel channels
- Assessment of Wigner release during fire accident during transport

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Conclusions

- UKAEA has a significant quantity of irradiated graphite
- Decommissioning of GLEEP has demonstrated that it can be done in a safe, effective and environmentally sound manner

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